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MINING WASTE EVALUATION STUDY, SOUTH PLATTE RIVER BASIN, COLORADO

Federal Water Pollution Control
Administration
Denver, Colorado

April 1968

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STUDY

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U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Platte River Basin Project
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FORWARD

This report represents one in a series of working documents prepared by The South Platte River Basin Project for the purpose of recognizing certain information not previously published by the Project. This particular report gives representative data and findings and conclusions developed from the Mining Waste Evaluation Study of 1966-1967. The two other reports in this series describe sand and gravel operations and impact of outdoor recreation in the South Platte River Basin. These activities are important to both the enforcement and long-range efforts of the Federal Water Pollution Control Administration assisting in the planning for water management and control and abatement of pollution in the South Platte River Basin and the Missouri River Basin.

TABLE OF CONTENTS

	Page
Forward	i
List of Tables	iii
INTRODUCTION AND BACKGROUND	1
UPPER SOUTH PLATTE RIVER BASIN	5
North Fork South Platte River	8
Middle Fork South Platte River	10
CLEAR CREEK BASIN	12
Clear Creek	13
West Clear Creek and North Clear Creek	16
Biological Studies Over Clear Creek Basin	25
ST. VRAIN CREEK BASIN - JAMES CREEK SUB-AREA	28
BIBLIOGRAPHY	31

LIST OF TABLES

Table Number	Title	Page
I	Dissolved Metals and pH Levels, North, Middle and South Forks of the South Platte River and their Tributaries August 1966 - January 1967	6
II	Dissolved Metals and pH Levels, Geneva Creek and Mosquito Creek Tributaries to the North and Middle Forks of the South Platte River - July 1966	7
III	Dissolved Metals and pH Levels, Clear Creek Basin August 1966 - January 1967	14
IV	Dissolved Metals, Clear Creek and its Tributary - West Clear Creek - August 1966	15

INTRODUCTION AND BACKGROUND

At the beginning of the century, mining was the major industry in the State of Colorado. Even today, this industry ranks fourth in the Colorado economy following manufacturing, recreation-tourism, and agriculture, with its annual value output around $340 million. Over the years through 1965, the cumulative value of various metals extracted from the mountains and soils of Colorado by deep and surface mining are as follows (in million dollars): gold-920, uranium-864, molybdenum-830, silver-605, zinc-421, lead-352, vanadium-121, copper-111, and tungsten-47 million dollars. Among non-metallics, sand and gravel production is most important with a cumulative value over the years through 1965 of 195 million dollars. Currently, major gains are being made in molybdenum, sand and gravel, uranium, vanadium, and zinc. There has been commercial development of other minerals, but again, many are practically unexploited, including the immense oil shale reserves in Western Colorado (1,2).

A recent report titled "Surface Mining and Our Environment" (3) gives perspective on Colorado compared to the nationwide picture. This data show that the State ranks 23rd highest as to land disturbed by strip and surface mining up to 1965, 15th highest as to land requiring reclamation, and 4th highest as to miles of streams adversely affected by mining activity. Such data do not include effects of deep mining, of which there has been considerable activity in Colorado over past decades.

Whereas the majority of mining now occurs in the western part of Colorado, the first strikes and many of the largest and most profitable mining ventures from 1860's to around 1910 were made on the eastern slopes

of the mountains. This activity was found in the South Park area, lower Cherry Creek, throughout most of the Clear Creek drainage, and in the upper parts of the St. Vrain Creek drainage. Past mining ventures have left wide marks of spoil and degradation. The State of Colorado, in seeking Federal grant monies to clean up mountain stream pollution, reports that more than 20,000 prospect holes and mine and mill dumps dot the State, the majority of which have been abandoned (4). Up to a few years ago, exploitation was invited in Colorado, and the eventual problems of pollution and land despoliation were not adequately foreseen. Since that time, urban pressures and recognition of causes and damages in the mining sector have become evident (5).

A previous report by the South Platte River Basin Project, and by the Technical Advisory and Investigations Branch, Cincinnati, Ohio, FWPCA (6), describes various causes of stream pollution associated with the nature of mining as follows:

1) Early mining was not subject to control and limited restrictions were imposed only after needs became apparent and following decades of accumulating neglect.

2) Mineral deposits were widely scattered and without protection of the environment, pollution became widespread.

3) A non-renewable resource was involved and after profitable exploitation, the mining areas were abandoned as near worthless. Consideration was not given to the areas that became an economic liability and upon abandonment the lands were returned to the public domain.

4) Mining claims did not contain provisions for the protection of environmental resources. Also, claims were transferred to new owners but cleanup responsibilities were not. Many original owners are deceased and original companies dissolved.

5) National armament, in particular, causes immediate exploita- of vital minerals, during which time restrictions for environmental protection may be relaxed. Changes in the economy also produce rapid acceleration and decline in the industry, thereby casting fluctuating demands on the responsible control agencies.

The above factors account for a situation where responsibilities were not delegated nor assumed and resulted in widespread land and water degradation. Toxic drainage flows out of abandoned mines, and mine and mill dumps when exposed to surface runoff contribute contaminants into a stream, possibly causing adverse water quality conditions throughout the entire length of the waterway. The polluted watercourse may become too acid, too alkaline, or contain excessive and toxic quantities of dissolved materials such as iron, manganese, copper, zinc, lead, arsenic and cadmium. The acid concentration while not lethal to fish and wildlife may bring about changes in their physical condition and rate of growth. In greater concentrations, acid may be directly lethal to fish or tend to suppress or prevent reproduction of the desirable fish species. Excessive amounts of dissolved metallics may be toxic to fish and wildlife, plants and aquatic insects, and highly detrimental in municipal and industrial water supplies. Mine drainage may also cause heavy discoloration of stream waters and be responsible for red and yellow iron deposits and coating of rocks and vegetation along the sides and bottom of the waste-receiving watercourse (3).

Specific instances of stream pollution caused by mining of metal reserves in the South Platte River Basin were investigated by the South Platte River Basin Project with assistance provided by the Technical Advisory and Investigations Branch, Cincinnati, Ohio, and the Salt Lake

City Laboratory of the Colorado River Basin Project, also FWPCA facilities.

Field studies were conducted in 1) the Upper South Platte River Basin area; 2) the Clear Creek Basin and 3) the St. Vrain Creek Basin. The various investigations comprised a network of more than 70 stations established and sampled during the latter part of 1966 and early 1967; special biological studies undertaken during summer 1966 in three exemplary areas; and numerous spot checks of mines, tailings and mine drainage with some sampling throughout the affected areas. The biological surveys focused upon the Geneva Creek drainage, tributary to the North Fork South Platte River near Grant, Colorado; the Mosquito Creek drainage tributary to the Middle Fork South Platte River near Alma and Fairplay, Colorado; and the main portions of Clear Creek between Silver Plume and Idaho Springs, Colorado.

The studies of mining wastes and their effects as conducted by the FWPCA for the South Platte River Basin give only a perspective to the overall problem existing in the Basin and the State of Colorado. These studies could not and did not consider any large number of mine waste sources but nevertheless indicate the widespread nature and approximate magnitude of the problem.

UPPER SOUTH PLATTE RIVER BASIN

Within the Upper South Platte River Basin area, early mining activity was spread along the upper reaches of the Middle and North Forks of the South Platte River, Tarryall Creek and many of the tributaries. Mining camps in the South Park area included Jefferson City, Hamilton, Fairplay, Como, Alma, Tarryall, Nelson's Bar, and Buckskin Joe, among many others (7).

The South Platte River Basin Project studies showed that stream pollution is most severe through the headwaters of the North Fork River downstream to the Roberts Tunnel, including Geneva Creek; and in the headwaters of the Middle Fork River above Fairplay, Colorado. Typical results for pH, manganese, iron, and heavy metal content of the waters of the North, Middle and South Fork Rivers and their tributaries over August 1966 - January 1967 are given in Table I. Also, results obtained from the special studies conducted in July 1966 in the Geneva Creek and Mosquito Creek drainage areas are shown in Table II.

Various criteria are available concerning effects of pH and dissolved metals upon water users, particularly as to prevailing fish-life. The Colorado Fish, Game, and Parks Department in a 1964 report guide for protection of fish and aquatic insects (8) prescribes allowable limits of toxic substances in natural waters as follows: aluminum - 0.1 to<5 mg/1, copper - 0.02 to 0.05 mg/1, cyanide - <0.05 mg/1, iron - 0.1 mg/1, lead - 0.1 mg/1, and zinc - 0.01 mg/1; however, heavy metals including copper, lead, zinc, and others are recommended not to exceed a total of 0.5 mg/1.

TABLE I

DISSOLVED METALS AND pH LEVELS
NORTH, MIDDLE AND SOUTH FORKS OF THE SOUTH
PLATTE RIVER AND THEIR TRIBUTARIES
August 1966 - January 1967

	Stream	Location	Flow (cfs)	pH	Manganese (mg/l)	Iron (mg/l)	Zinc mg/l	Copper (mg/l)	Lead (mg/l)	Cadmium (mg/l)	Remarks
NORTH FORK	North Fork R.M. 47.8 [a]	Imm. above Handcart Gulch	5	6.8	0.08	0.37	0.07	0.02	< 0.1	< 0.02	pH low of 5.5
		CONFLUENCE OF HANDCART GULCH - RM 47.7									
	Handcart Gulch at mouth	Tributary	1	3.7	0.32	11.4	0.16	0.14	<0.1	<0.02	
	North Fork R.M. 40.4	0.5 mi. above Roberts Tnl.	8	7.1	0.17	0.36	0.6	< 0.03	<0.1	<0.02	
		CONFLUENCE WITH ROBERTS TUNNEL - RM 39.9									
		CONFLUENCE OF GENEVA CREEK - RM 39.1									
	Geneva Creek R.M. 12.2	Tributary	2	3.5	1.66	11.3	0.54	0.07	<0.1	-	
	Geneva Creek R.M. 1.7	Tributary	30	7.1	0.16	0.48	0.07	0.02	<0.1	<0.02	Iron high of 1.2 mg/l
	North Fork RM 31.9	Near Shawnee	148	7.4	0.09	0.20	0.16	<0.03	<0.1	<0.02	Iron high of 0.6 mg/l
	North Fork R.M. 0.8	Near mouth	236	7.4	0.04	0.18	0.09	<0.03	<0.1	<0.02	Iron high of 0.27 mg/l
MIDDLE FORK	Middle Fork RM 42.8	Imm. above Montgomery Rsvr.	11	7.2	0.04	0.15	0.16	<0.03	<0.1	<0.02	
		CONFLUENCE WITH MOSQUITO CREEK - RM 35.3									
	Mosquito Creek at mouth	Tributary	10	7.6	0.13	0.96	0.33	<0.03	<0.1	<0.02	Iron high of 1.7 mg/l
	Middle Fork RM 32.0	Road to Sacramento Gulch	29	7.9	0.06	0.7	0.14	<0.03	<0.1	<0.02	Iron high of 1.8 mg/l
	Middle Fork RM 1.6	First bridge above mouth	31	8.3	0.09	0.42	0.03	<0.03	<0.1	<0.02	Iron high of 1.1 mg/l
S.FORK	South Fork RM 37.1	Above Rich Campground	4	8.0	0.01	0.26	0.09	<0.03	<0.1	<0.02	
	South Fork RM 18.5	2.0 miles above Antero Rsvr.	8	8.5	0.02	0.20	0.05	<0.03	<0.1	<0.02	
	South Fork RM 1.5	Near mouth	17	8.7	0.02	0.13	0.06	0.02	<0.1	<0.02	

[a] RM - River Mileage measured from mouth of respective stream

TABLE II

DISSOLVED METALS AND pH LEVELS
GENEVA CREEK AND MOSQUITO CREEK
TRIBUTARIES TO THE NORTH AND MIDDLE FORKS
OF THE SOUTH PLATTE RIVER
July 1966

	Stream	Location	Flow (cfs)	pH	Manganese (mg/l)	Iron (mg/l)	Zinc (mg/l)	Copper (mg/l)	Lead (mg/l)	Remarks
GENEVA CREEK	Geneva Creek RM 13.5	200 yds. above large iron ore deposits	1	4.1	1.4	0.4	-	-	-	
	Geneva Creek RM 12.5	Above Jackwhacker Gulch	2	3.3	1.7	7.8	-	-	-	
	Geneva Creek RM 6.8	Imm. below Duck Creek	10	5.2	0.4	1.1	-	-	-	
		CONFLUENCE OF SCOTT GOMER CREEK - RM 4.3								
	Scott Gomer Creek at mouth	Sub-Tributary	31	7.3	< 0.1	0.8	-	-	-	
	Geneva Creek RM 2.5	Near mouth	52	7.2	0.1	0.7	-	-	-	
MOSQUITO CREEK	Mosquito Creek MR. 7.0	2.0 miles above So. Mosquito Creek	-	-	< 0.1	< 0.1	< 0.02	< 0.02	< 0.01	
		CONFLUENCE WITH SO. MOSQUITO CREEK - RM 5.0								
	So. Mosquito Creek RM 1.2	Sub-Tributary above London Mine drainage	-	-	< 0.1	0.1	0.04	< 0.02	0.01	< 0.5 mg/l Aluminum
	So. London Mine Drainage	Discharge into Sub-Tributary at RM 1.0	-	-	0.4	3.6	4.5	0.10	0.04	0.6 mg/l Aluminum
	So. Mosquito Creek RMO.1	Sub-Tributary at mouth	-	-	0.3	3.7	0.9	0.06	1.00	2.7 mg/l Aluminum
	Mosquito Creek RM 4.1	0.9 miles below So. Mosquito Creek	-	-	0.2	1.2	0.28	< 0.02	0.09	
	Mosquito Creek RMO.1	At mouth	-	-	< 0.1	0.4	0.12	< 0.02	0.03	

Further comment to the above guidelines are offered by a previous FWPCA report on aquatic life resources of the South Platte River Basin in Colorado (9). This report suggests that pH level should not decrease below 4.5, and within soft, low-alkalinity waters the concentrations of lead, zinc, and iron should not exceed 0.1, 0.5 and 1.0 mg/l., respectively. However, where these metals occur in combination, the resulting effect is an additive one whereby:

$$F = \frac{C_i}{T_i} + \frac{C_2}{T_2} + \frac{C_3}{T_3}$$

with C = concentration of various metals in the stream.

T = threshold concentration numerically described above and

F should not exceed 1.0.

This relationship was verified by fish collection studies undertaken in the area affected by mining wastes and related to the "F" value as defined. The findings are summarized as follows:

	Waters with "F" Less than 1.0	Waters with "F" Greater than 1.0
No. Sampling Stations	58	42
% Fish Captured	91	9

North Fork South Platte River

Along the upper end of the North Fork, bog iron ore is prevalent in the Handcart Gulch area and these deposits mined in past years are expected to be reworked in the near future. Heavy red and white layers of limonite are found on the stream bottom and rocks of Handcart Gulch and the upper portion of the North Fork River downstream to Kenosha Creek (RM 42.4). Aquatic life and fish are virtually non-existent throughout the area.

Further downstream on the North Fork within the Geneva Creek watershed, bog ore is found in appreciable deposits near the headwaters of Geneva Creek (RM 13.2) and limited surface mining is currently being undertaken in the area by the Stony Point Development Company. The pH level of the streamflow through the mine workings is about 3.3. Acidity and iron leached from the exposed iron deposits are the primary damaging pollutants to Geneva Creek throughout its length. Heavy reddish and white layers of limonite were found on the stream bottom, the lowlands, rocks and vegetation downstream to Scott Gomer Creek (RM 4.3). Very low pH levels are encountered and virtually no alkalinity is present in Geneva Creek downstream to Scott Gomer Creek. The latter sub-tributary with its relatively large inflow permits limited fish stocking downstream and the fish persist long enough for some sport by the public. Fish planted by mistake in the public park area above this inflow in 1965 were later found dead along the stream banks.

In the North Fork, from the headwaters to Geneva Creek, the "F" ratio for dissolved metals approaches and may even exceed 1.0. Furthermore, no large fish have been reported throughout this area, despite the number of fish stocked and the miles of stream restricted to the general public (10). Measures previously suggested for abating pollution caused by the iron ore deposits include diversion of streamflow around the deposits, and/or accelerated mining to remove the iron ore in the shortest possible time, followed by proper stabilization of the residual ores (9).

From available information, waters of the lower North Fork River are marginal in terms of supporting fish and aquatic life. Water imports via the Roberts Tunnel transported down the North Fork River

serve to provide dilution of the mineral content but these flows are not continuous throughout the year. In the fall of 1964 after imports had ceased, heavy deposits of limonite were observed on the stream bottom and rocks extending downstream to Deer Creek (RM 19.9) and beyond (10).

Middle Fork South Platte River

The upper portion of the Middle Fork River is considerably affected by mining wastes originating in the Mosquito Creek area. Below Fairplay, the metal content in the stream approximates levels found in the lower North Fork River except for higher iron concentrations.

Mosquito Creek and its main sub-tributary of South Mosquito Creek drain watersheds south and north of London Mountain which in turn contains large deposits of precious and other mineral ores extensively mined in the past and currently mined. Most of the internal drainage from London Mountain emerges at the South London Tunnel and enters into South Mosquito Creek at RM 1.0. Other drainage accrues throughout the area, particularly from many exposed tailing piles along the banks of Mosquito and South Mosquito Creeks. South Mosquito Creek maintains a channel through the extensive tailing deposits covering one mile of the downstream reach of the valley. It is also noted, much of the drainage area of both streams has been partially or completely denuded of vegetation and trees resulting from the hectic mining, milling and concentrating activity of past decades. With rainfall, appreciable erosion and runoff of soil and exposed tailings may be expected into the watercourses (9).

The studies in the Mosquito Creek area in July 1966 showed the South London Mine Tunnel drainage with a pH of 7.1 to 7.5, zinc content

of 4.3 to 4.8 mg/l, iron from 0.4 to 6.8 mg/l, copper from 0.08 to 0.14 mg/l, and aluminum from 0.5 to 0.8 mg/l. South Mosquito Creek also receives considerable leaching of iron, zinc, copper and lead from exposed tailings along the stream. Additionally, the large quantities of rock flour swept from the tailing piles into the waters results in drastic reduction of bottom animals, fish and other aquatic life through South Mosquito Creek and lower Mosquito Creek.

The "F" ratio for iron, zinc and lead in Mosquito Creek below South Mosquito Creek ranged from 2.6 to 1.0 at the stream mouth. The erosion of tailings into the waterways were found more detrimental than the Mine Tunnel drainage and a previous recommendation has been made that the exposed tailing piles should be buried and planted over with rock, soil, and vegetation, thereby stabilizing the surfaces against erosion. Suggestions were also made that iron, and particularly zinc content of the South London Mine Tunnel drainage be sufficiently reduced (9).

CLEAR CREEK BASIN

Clear Creek Basin has experienced a long history of mining activity and some of the earliest and richest gold and silver strikes were made in this area with many communities developing around these sites. After the richest and most accessible deposits were extracted, the majority of communities became ghost towns, whereas others barely sustained themselves until the 1940's, when Denver started its large growth, and increased attention led to revival and renewal of these mountain towns. Today, these communities primarily cater to the recreation and tourist trade as evidenced by diligent efforts to preserve and restore large portions of Central City and Georgetown, Colorado, to their nineteenth century appearance.

Present day mining activity consists chiefly of placer mining along North Clear Creek with some sites serving as tourist attractions, particularly in the Central City-Blackhawk area; a few small mining operations in the Idaho Springs and Central City areas and a milling operation at Central City; reprocessing of old tailing piles in the vicinity of Silver Plume at the headwaters of Clear Creek; the Schwartzwalder uranium mine, approximately 8 miles northwest of Golden above Ralston Reservoir on Ralston Creek; and the Urad molybdenum mine near the headwaters of the West Fork of Clear Creek and Berthoud Pass. A countless number of abandoned or inactive mines, tailing piles, mills, dumps and other mining remains are also scattered throughout the basin. Dense concentration of mining remnants occur in the Georgetown-Silver Plume area, around Idaho Springs, and in the Central City-Blackhawk area (1,9).

The major consequence of mining discharges in the Clear Creek basin are the excess quantities of heavy metals entering the streams with extensive damage to the aquatic life and fisheries resources of the area. The Clear Creek watershed receives very heavy demand for outdoor recreation use and any damage to the streams represents a direct loss to the tourist and recreation-oriented communities, to adjoining regions, and to the State of Colorado (9).

Water quality sampling was conducted over Clear Creek from August 1966 - January 1967, particularly for iron, manganese and various heavy metals. Special studies were also undertaken in August 1966 along West Fork Clear Creek (RM 47.1), and along Clear Creek from Silver Plume (RM 54.9) downstream past Idaho Springs (RM 36.8) to three miles below the confluence of North Clear Creek (respective RM's of 30.0 and 26.6). The more pertinent water quality data from these studies are shown in Tables III and IV. Additional investigation was directed to specific mines and mine drainage which provided a better understanding of the overall pollution problems in the Clear Creek Basin.

Clear Creek

In assessing effects of heavy metals and associated pollutants upon aquatic life resources of the Clear Creek basin, the criteria and guidelines previously described for the Upper South Platte River Basin are applied herein. The majority of mainstream Clear Creek flows contain heavy metal concentrations which are decidedly toxic to fish and other aquatic life. Principal toxic components are iron, zinc, lead, and manganese.

TABLE III

DISSOLVED METALS AND pH LEVELS
CLEAR CREEK BASIN
August 1966 - January 1967

Stream	Location	Flow (cfs)	pH	Manganese (mg/l)	Iron (mg/l)	Zinc (mg/l)	Copper (mg/l)	Lead (mg/l)	Cadmium (mg/l)
Clear Creek RM 57.9	5.0 mi. above Silver Plume	13	7.6	0.03	< 0.04	0.08	< 0.03	< 0.1	< 0.02
Clear Creek RM 51.8	1.5 mi. above Georgetown	23	7.5	0.48	0.72	4.32	0.04	1.0	0.04
	CONFLUENCE OF SOUTH CLEAR CREEK - RM 50.3								
Clear Creek RM 49.1	1.0 mi. below Georgetown	25	8.0	0.27	0.48	4.55	0.03	0.6	< 0.02
	CONFLUENCE OF WEST CLEAR CREEK - RM 47.5								
West Clear Creek RM 9.6	Tributary - Imm. above Woods Creek	7	7.7	0.19	0.10	0.13	< 0.03	0.2	< 0.02
West Clear Creek at mouth	Tributary	21	7.7	0.61	0.45	0.12	< 0.03	0.2	< 0.02
Clear Creek RM 47.0	1.0 mi. above Lawson	45	7.5	0.26	0.30	0.54	< 0.03	< 0.1	0.02
	CONFLUENCE OF FALL RIVER - RM 41.8								
	CONFLUENCE OF CHICAGO CREEK - RM 39.5								
Clear Creek RM 35.7	1.1 mi. below Idaho Springs	97	7.4	1.14	1.78	0.90	0.12	< 0.1	< 0.02
	CONFLUENCE OF NORTH CREEK - RM 30.0								
North Clear Creek RM 9.9	Tributary - 2 mi. ab. Blackhawk	5	7.3	0.02	0.11	0.12	0.02	< 0.1	< 0.02
Gregory Gulch at mouth	Sub-Tributary at Blackhawk	0.3	7.3	1.18	5.1	1.08	0.14	< 0.1	< 0.02
North Clear Creek RM 6.8	Tributary - 0.5 mi. below Blackhawk	3	6.2	6.1	20.0	2.74	0.24	< 0.1	< 0.02
North Clear Creek at mouth	Tributary	3	4.8	4.0	6.5	2.79	0.31	< 0.1	< 0.02
Clear Creek RM 26.6	3 mi. below North Clear Creek	93	6.9	1.03	1.94	0.91	0.09	< 0.1	< 0.02
Clear Creek RM 18.7	1 mi. west of Golden, Colorado	166	7.4	0.94	0.88	0.71	0.07	< 0.1	< 0.02

TABLE IV

DISSOLVED METALS
CLEAR CREEK AND ITS TRIBUTARY
WEST CLEAR CREEK
August 1966

	Stream	Location	Flow (cfs)	Manganese (mg/l)	Iron (mg/l)	Zinc (mg/l)	Copper (mg/l)	Lead (mg/l)	Remarks
	Clear Creek RM 54.9	2.0 mi. above Silver Plume	17	< 0.1	0.2	0.02	< 0.02	0.01	
	Clear Creek RM 49.1	1.0 mi. below Georgetown	59	< 0.1	0.2	0.28	< 0.02	0.04	
	Clear Creek RM 45.5	At Lawson, Colorado	110	0.3	0.6	0.21	< 0.02	0.05	
	Argo Mine Drain RM 36.8	Enters Clear Creek at Idaho Springs	0.3	85.0	160.0	46.5	5.69	0.02	20.5 mg/1. Aluminum
	Clear Creek RM 35.7	1.1 mi. below Idaho Springs	130	0.5	1.2	0.33	0.04	0.03	
	North Clear Creek at mouth	Tributary entering Clear Cr.at RM 30.0	4	3.2	7.5	1.56	0.10	0.02	0.9 mg/1. Aluminum
	Clear Creek RM 26.6	3 mi. below North Clear Creek	133	0.6	1.5	0.34	0.02	0.05	0.5 mg/1. Aluminum
WEST CLEAR CREEK	West Clear Creek RM 9.6	Imm. above Woods Creek	12	0.2	0.2	0.03	< 0.02	< 0.01	
		CONFLUENCE WITH WOODS CREEK - RM 9.4							
	Woods Creek RM 1.4	Sub-Triburary above Urad Mine drainage	3	0.2	0.2	< 0.02	< 0.02	< 0.01	
	Urad Mine Drainage	Discharge into Sub-Tributary at RM 1.2	0.5	41.0	13.6	4.50	0.07	0.04	8.3 mg/1. Aluminum
	Woods Creek at mouth	Sub-Tributary below Urad Mine drainage	7	1.3	0.8	0.13	< 0.02	< 0.01	0.7 mg/1. Aluminum
	West Clear Creek RM 5.4	4 mi. below Woods Creek	25	0.6	0.3	0.07	< 0.02	< 0.01	

Principal sources of metallics are in the Silver Plume area, West Clear Creek inflows, the Argo Mine Drain, and North Clear Creek inflows. Numerous other sources also exist throughout the area chiefly in the form of acid mine drainage.

During August 6-10, 1966, the "F" ratio for iron, zinc and lead in Clear Creek waters (taken from Table IV) was 0.4 above Silver Plume, exceeded 1.0 below Georgetown, and increased in the downstream direction to a maximum of 2.7 recorded below the North Clear Creek confluence. The additional data collected over the period August 1966 to January 1967 (Table III) showed much higher "F" ratios in part due to lower streamflows, but mostly attributed to specific mining functions, such as cleaning, flushing, stripping, etc., particularly in the Silver Plume area. The August 1966 - January 1967 data showed an average "F" ratio of 0.2 above Silver Plume, compared to a "F" level of 19.4 above Georgetown, and a level of 15.6 being observed one-mile below Georgetown. Further downstream, the "F" ratio was 1.4 above Lawson, increasing to 3.6 directly below Idaho Springs, and 3.8 at a point 3 miles below the North Fork confluence. Zinc and lead are the principal toxic components in the upstream portions of Clear Creek, whereas iron and zinc are of greatest significance in the downstream sections.

West Clear Creek and North Clear Creek

West Clear Creek and North Clear Creek both suffer adverse effects from mining activities, associated drainage, and the like. Pollution effects are particularly severe along the lower 9 - 10 miles of North Clear Creek extending from Blackhawk to the stream mouth. In August 1966, the "F" ratio in the West Clear Creek watershed was around 0.2 at

the upper ends of West Clear Creek and Woods Creek, 1.1 at the mouth of Woods Creek, and 0.5 at the mouth of West Clear Creek. Iron and manganese are of greatest toxic significance in this area, whereas drainage and processing wastes which may originate from the Urad mine and mill of the Climax Molybdenum Company represent the most important sources of potential or actual pollution in the watershed.

In the North Clear Creek watershed, which contains the historic mining towns of Central City and Blackhawk, past and present mining activities (mostly placer mining) have converted the stream into an extensive spoils area with stripped-out sections and piles of rock and rubble strewn about. Numerous abandoned mines and tailing piles widely dispersed over the area also contribute considerable drainage into the streams. The waters of North Clear Creek are heavily laden with dissolved manganese, iron, zinc, and copper. The study results collected for North Clear Creek over August 1966 to January 1967 showed a "F" ratio of 0.35 for the stream two miles above the Blackhawk-Central City complex; Gregory Gulch waters with a small flow but having a "F" ratio of 7.2; and North Clear Creek 0.5 miles below Blackhawk and near the mouth respectively showing "F" levels of 25.5 and 12.1.

Considering the entire Clear Creek basin, extreme maximum levels of toxicity were found for North Clear Creek below Central City-Blackhawk and for Clear Creek in the Silver Plume-Georgetown area.

Individual Mining Sites - Clear Creek in the Silver Plume-Georgetown Area

Representative mining activity in the Silver Plume-Georgetown area

includes the Silver King Mine, a tourist attraction in Silver Plume; the Cotter Corporation in Silver Plume which is reworking an old mine dump by chemical separation procedures for recovery of lead, zinc and silver; and the Capital Prize Mine in Georgetown being rehabilitated in 1966 by the Oxley Petroleum Company for future recovery of metals. Observations made in 1966 showed about 5 gpm of rust-colored water originating from the Silver King Mine entering into Clear Creek; processing wastes from the Cotter Corporation activity were being released into two holding ponds with no apparent overflow to Clear Creek; and approximately 10 gpm of drainage from the Capital Prize Mine was being discharged onto a tailing pile located about 350-yards from Clear Creek.

The Urad Operations - West Clear Creek

The Urad mining and milling operations of the Climax Molybdenum Company located a few miles west of the town of Empire, Colorado, at the foot of Berthoud Pass and in the West Clear Creek drainage area, began full-scale processing operations in September 1967. The presently defined molybdenum ore deposit at the Red Mountain site is estimated around 12 million tons, expected to produce molybdenum ore at a capacity of 5000 tons per day over the next seven or eight years. Exploration is also continuing on a much larger molybdenum deposit estimated at 240 million tons anticipated to be found on the north side of Red Mountain and reserved for future processing. The mined rock is transported to the crushing plant and the concentrator where the ore is ground-fine in the ball mills, then pumped to the flotation chambers for separation of molybdenite from the heavier waste material. In succeeding steps, the molybdenite is

subjected to chemical leaching for removal of lead, then filtered and dried into the final product (11,12,13).

In June 1966, the Urad project under development was producing 225 gpm of waste drainage. This drainage was discharged into a (lower) pond mixing with the waters of Woods Creek and overflowing into the same stream. The downstream waters of Woods Creek were quite turbid and after entering West Clear Creek caused discoloration of the latter stream over an appreciable distance. This drainage sampled in August 1966, contained high concentrations of iron, manganese, zinc, and aluminum (Table IV).

Reported information indicates that a dam and reservoir has been recently constructed upstream of the Urad site to retain up to an 100-year flood and a concrete pipeline has been buried from the reservoir site two-miles down the valley to accommodate and transfer the streamflow in Woods Creek beneath the mine's tailing pile. Also, mine drainage and processing wastes will be released into a tailing pond with decantation to the lower pond previously mentioned. Water in the lower pond will be recycled for process use in the mill and there will be no overflow to the creek except during times of excessive runoff. Although much consideration has been given to the waste handling and treatment aspects of the Urad operation, surveillance and evaluation must be continued to prevent stream pollution and indescriminate despoliation of lands in this area (6,11,12,13).

McClellan Mine - Clear Creek at Dumont, Colorado

The McClellan Mine is situated adjacent to Clear Creek east of Dumont, Colorado and about 5 miles downstream of West Clear Creek. This abandoned operation contributes about 20 gpm of mine drainage containing particularly high amounts of iron, manganese and zinc, and moderate amounts of copper and cadmium, which enters directly into Clear Creek.

Individual Mining Sites - Clear Creek at Idaho Springs, Colorado

In the Idaho Springs area, visits were made in 1966 to three operations considered important in this locale, including the Blue Ribbon Tunnel, the Central Tunnel No. 5 ("Big Five"), and the Argo Tunnel. The Blue Ribbon Tunnel on the southeast edge of Idaho Springs is presently a tourist attraction and has a drainage of 3 - 5 gpm containing moderate levels of iron and manganese entering into Clear Creek. The Central Tunnel No. 5 on the west edge of Idaho Springs was originally built for extracting and hauling ores and collecting the drainage from several mines in the area. The tunnel is presently inactive and drains at the rate of 10 - 15 gpm into a pond directly adjacent to Clear Creek. Appreciable percolation is probable into Clear Creek. The pond waters were found quite acidic with a pH level of 2.7, total dissolved solids of 2820 mg/l and with metal concentrations of 118 mg/l iron, 43 mg/l manganese, 16 mg/l zinc, 4.3 mg/l copper, and 0.1 mg/l cadmium.

The 7.5-mile Argo Tunnel was completed in 1893 for the purpose of draining numerous mines over the Central City to Idaho Springs area and for hauling ore from the many interconnecting mines for processing at the Argo mill located at Idaho Springs. The terminus of the Argo

Tunnel, and the Argo Mill and its associated tailing pile are situated on the east side of Idaho Springs. The Tunnel and the Mill have been inactive since 1942 but drainage continues unabated into Clear Creek at the rate of about 150 gpm. The Argo Tunnel probably represents the largest single identifiable mine drainage in the Clear Creek basin. The Argo Tunnel drainage is released onto the tailing pile at the mill site, which in turn, is another important source of metals contribution to the stream, particularly during times of heavy rainfall associated with erosion of the tailing pile. Sampling results obtained on the Argo Tunnel drainage in June 1966, and again in August 1966 (see Table IV), show the gross pollutional nature of this effluent. The drainage is quite acidic with a pH level of 2.7, total dissolved solids of 2940 mg/1 and very high metals concentrations as follows: manganese - 76 to 85 mg/1; iron - 160 to 175 mg/1; zinc - 40 to 47 mg/1; copper - 5.7 to 6.9 mg/1; cadmium around 0.15 mg/1 and aluminum 21 mg/1. Daily amounts of dissolved iron and zinc originating from this single source are 285 pounds and 83 pounds, respectively.

Individual Mining Sites - North Clear Creek

Three operations were selected as representative of the mining activity in the Central City-Blackhawk area which include 1) placer mining by the A and S Minerals Company on Elk Creek, tributary to Pine Creek which, in turn, is tributary to upper North Clear Creek about 6 miles above Blackhawk; 2) the Incline Tunnel terminating under a large tailing pile and entering North Clear Creek at the north edge of Blackhawk; and 3) the Glory Hole Mill operations about one-half mile south of Central City and draining into Illinois Gulch which, in turn, enters Russell Gulch with its

confluence about 3-miles above the mouth of North Clear Creek.

The placer mining activity on Elk Creek for the recovery of gold represents a small operation but has been associated with frequent complaints of excessive silt and sediment flowing down Elk Creek and Pine Creek caused by the mining activity. In July 1966, it was observed that earthen dikes had been built across Elk Creek to provide two small settling ponds, and a third pond was near completion within the stream below the placer mining site. Visual findings indicated that even with these facilities, waste control measures at that time were inadequate, and excessive turbidity was observed throughout the lower end of Elk Creek.

The Incline Tunnel emerges under a large tailing pile located behind the Texaco Inc. gasoline service station in Blackhawk with direct access into North Clear Creek. This tunnel has been abandoned and has since collapsed under the tailing pile. Because the tailing pile directly abuts the stream, entry of the mine drainage could not be separately distinguished from the stream, and furthermore could not be sampled. The drainage is reported as greater than 100 gpm and North Clear Creek flowing alongside the tailing pile is observed as highly rust-colored, turbid a and acidic with a pH level around 5.2.

The Glory Hole Mill south of Central City and one-quarter mile from the Glory Hole Mine is operated intermittently and the mill effluent is discharged into a small pond with access to Illinois Gulch, Russell Gulch and eventually North Clear Creek. No other data is available on the mill processing or the magnitude and nature of the resulting waste effluents.

Schwartzwalder Uranium Mine - Ralston Creek

Another important mining operation is the Schwartzwalder Uranium Mine located above Ralston Reservoir on Ralston Creek. The waters of Ralston Creek eventually enter into the lower end of Clear Creek within the Denver Metropolitan Area. The Schwartzwalder Mine is more precisely described as 8 miles northwest of Golden, Colorado, 2-miles above the high-level impounded waters in Ralston Reservoir and 4-miles above the dam.

Ralston Reservoir is a vital structure in the transmountain water diversion system of the Denver Water Board. Ralston Reservoir, in addition to receiving Ralston Creek waters, provides intermediate storage for waters received from the Frazer-Vasquez-St. Louis-Williams Fork watersheds on the Western Slope. The transmountain waters are conveyed through the Moffat Water Tunnel, down South Boulder Creek to Gross Reservoir near Boulder, Colorado, then via pipeline to Ralston Reservoir and another pipeline from Ralston Reservoir to the Moffat Filter Plant which provides finished water for the city and county of Denver and adjoining areas. Upper Long Lake located adjacent to Ralston Reservoir also merits consideration in that Ralston Creek flows are diverted into this storage facility about 1.5 miles below the Schwartzwalder Mine and eventually used as domestic water supply by the North Table Mountain Water District.

The Schwartzwalder Mine was discovered in the late 1940's and initially developed by The Denver-Golden Corporation. Uranium ore was mined over several years and the mine became known as the richest

uranium producer on the Eastern Slope of the Rocky Mountains. In recent years the mine has been closed, but in 1966, vested interest was sold to the Cotter Corporation. Reopening of the Mine was planned in 1966 but it is not known whether these operations have commenced (14,15).

Previous studies conducted by the Colorado State Department of Public Health showed very high radioactivity levels in the drainage leaving the Mine and in these same liquors after settling in a small waste retention pond and upon their discharge into Ralston Creek. Over 1963 to 1965, the mine drainage was rated at 80 gpm and various sampling results on this drainage indicated suspended and dissolved gross alpha values of 6020 and 2050 uuc/l respectively; suspended and dissolved gross beta values of 3970 and 380 uuc/l respectively; and Ra-226 levels ranging from 51.5 to 142.1 uuc/l. Over the same period, the receiving creek and reservoir waters have ranged from 0.2 up to 11.4 uuc/l in Ra-226 content.

Subsequent studies conducted by the Colorado State Department of Public Health in March 1966 showed the pond effluent with 1363 uuc/l gross alpha in suspended form, 1075 uuc/l gross alpha in dissolved form, and 86.7 uuc/l Ra-226. Ralston Creek, one-half mile below the mine effluent, had a dissolved gross alpha count of 219 uuc/l and 7.9 uuc/l Ra-226.

Additional sampling was conducted by the South Platte River Basin Project during September - November 1966 of the effluent from Upper Long Lake taken at the North Table Mountain Filter Plant and of Ralston Creek at the Ralston Reservoir outlet.

This data showed that the water supply samples contained average levels of 1.0 uuc/l total gross alpha and 0.04 uuc/l Ra-226, whereas, the waters leaving Ralston Reservoir demonstrated average levels of 52 uuc/l total gross alpha and 0.18 uuc/l Ra-226. Although the 1966 study results show that radioactivity levels found in the stream and reservoir waters were considerably below the radioactivity limits established as safe in the United States Public Health Service Drinking Water Standards, some of the earlier results of 1963-1964 approached and on occasion exceeded the generally accepted limit of 3.0 uuc/l Ra-226. In view of past conditions and increased uranium ore production expected at the Schwartzwalder Mine, a continuous surveillance system should be established and maintained for determining radioactivity levels over the area. It is also likely that further corrective and/or waste treatment measures should be incorporated at the Schwartzwalder Mine.

Biological Studies Over Clear Creek Basin

As part of the special study of August 1966, samples were also taken of fish and bottom animal populations and attached algae found along Clear Creek from Silver Plume extending downstream past the confluence with North Clear Creek. Fish population data clearly showed that most of the mainstream of Clear Creek contained waters toxic to fish. The number of fish captured in trap-nets over four equivalent sampling days is given as follows: 4 fish above Silver Plume, 6 fish one-mile below Georgetown, no fish captured at either Lawson or directly below Idaho Springs, and one fish found 3 miles below the North Clear Creek confluence. Greater fish, bottom animal, and algal populations than otherwise expected one-mile below

Georgetown were attributed to large quantities of untreated municipal sewage originating from Georgetown and the ability of this fecal material and organic solid matter to adsorb metals thereby mitigating their toxic effect upon fish and aquatic life.

Attached algae in Clear Creek were found more tolerant to metals than fish life. After the addition of wastes, especially domestic wastes from Georgetown, the number of attached algal cells and chlorophyll manufactured by the algal cells increased. Algae cells were adversely affected in North Clear Creek probably due to many factors such as heavy metals (F ratio in excess of 10), turbidity (up to 126 units), and suspended solids (average of 41 mg/l). Clear Creek below the confluence of North Clear Creek had a relatively impoverished algal flora evidenced by minimum chlorophyll concentrations reflecting a low rate of algal growth.

Plant material in a stream is converted into animal tissue by bottom animals which, in turn, serve as a primary source of food for predatory fish as trout, bass, etc. Because of nutrient additions in the Georgetown area and induced algal growth, bottom animals directly below Georgetown using algae as food source, showed increases in both quantity and variety. Further downstream, the variety of bottom animals decreased as toxicity became greater and the more sensitive forms were eliminated. Below the confluence of North Clear Creek, the number of bottom animals again increased but variety continued to decrease. A few kinds of tolerant organisms were present in relatively large numbers and this was attributed to elimination or reduction of the more sensitive animals of the bottom community.

In the Clear Creek basin, pollution abatement and restoration of the fisheries are highly desirable for sustaining the recreational industry commensurate with large future growth expected over the area. Reduction in quantity of heavy metals discharged by mining wastes in the various waterways is essential. A previous report by the FWPCA emphasizes that a 90 percent reduction of heavy metals contained in mining discharges (especially iron, zinc and lead) is required to make the mainstream of Clear Creek acceptable for sustained fish propagation (9).

ST. VRAIN CREEK BASIN - JAMES CREEK SUB-AREA

The western half of Boulder County directly east of the Continental Divide has experienced a long and fruitful history of mining activity and many of the old mining towns such as Ward, Raymond, and Jamestown still remain. This section of the report will consider only the region in the vicinity of Jamestown, Colorado, and three examples of mining within the James Creek area. James Creek enters into Lefthand Creek 19 miles from the point where Lefthand Creek in turn enters into St. Vrain Creek in the vicinity of Longmont, Colorado. Another stream of importance is Little James Creek tributary to James Creek.

Visits were made to three sites in the above-described area including 1) the J-Albine Mine Tunnel on Lefthand Creek below Ward, Colorado and 8.7 miles upstream of James Creek; 2) the Curie Springs located on James Creek in Springdale, Colorado and two-miles southeast of Jamestown, Colorado; and 3) the Burlington Mine situated one-mile up Little James Creek in the vicinity of Jamestown. All three sites contributed drainage to the receiving stream.

J - Albine Mine Tunnel and The Curie Springs

Little information was obtained on the J-Albine Mine Tunnel except for the presence of a discharge rated around 5 gpm into Lefthand Creek. The Curie Springs is a small resort spa with baths having been established on the site and bottled water sold for alleged cures of various physical ailments. A small flow of about 2 gpm emanates from the Curie Springs with discharge into James Creek. Previous sampling of this source by the

Colorado State Department of Public Health in 1965 showed a pH level around 5.8, and radioactivity in terms of gross alpha of 76 uuc/1 and Ra-226 content of 5.7 uuc/1. Project study undertaken in October 1966 indicated a gross alpha radioactivity level of 74 uuc/1, Ra-226 of 13 uuc/1, together with relatively high levels of iron - 5.7 mg/1, manganese - 0.6 mg/1, and lead - 0.3 mg/1.

The Burlington Mine - Jamestown, Colorado

The Burlington Mine is owned and operated by the General Chemical Company, Division of Allied Chemical Corporation for the production of fluorspar ore ($Ca F_2$). The ores are conveyed from the mine site via trucks to the company-owned Valmont Mill at Boulder, Colorado for further processing. Drainage from the sixth (600-feet deep) and tenth (1140-feet deep) working levels at the Burlington Mine is collected into sumps, and pumped, generally at night, to the surface into a small earthen pond. Total pumped volume approximates 25,000 gallons per day and the pond liquors intermittently overflow into Little James Creek.

Sampling and analysis undertaken by The Colorado State Department of Public Health in January - February 1966 showed that the ponded liquors contained the following waste constituents: total dissolved solids - 5250 mg/1, sulfates - 2350 to 2830 mg/1, fluorides -- 440 to 500 mg/1, iron - 16 to 30 mg/1, manganese - 1.1 to 10 mg/1, copper - 0.9 to 1.8 mg/1, lead - 0.2 mg/1, and radioactivity in terms of dissolved gross alpha - 1265 to 6850 uuc/1 and Ra-226 content of 14.3 to 18.4 uuc/1. Data also obtained for Little James Creek at its mouth were as follows: total dissolved solids - 3180 mg/1, sulfates - 1820 mg/1, fluorides - 240 mg/1,

iron - 4.0 mg/l, manganese - 1.0 mg/l, copper - 0.6 mg/l, lead - 0.13 mg/l, and radioactivity as dissolved gross alpha - 930 uuc/l and Ra-226 of 1.7 to 2.0 uuc/l.

Follow-up studies by the South Platte River Basin Project during September - November 1966 provided additional water quality information on Little James Creek and on James Creek. The waters of Little James Creek sampled at its mouth contained the following amounts of waste material: total dissolved solids - 3570 mg/l, zinc - 54 to 175 mg/l, iron - 3.1 to 27 mg/l,manganese - 6.6 to 8.6 mg/l, lead - 0.2 to 1.1 mg/l, copper - 1.0 to 3.7 mg/l, cadmium - 1.0 to 1.5 mg/l, gross alpha radioactivity - 570 to 4100 uuc/l and Ra-226 of 1.9 to 12 uuc/l. All of the waste parameters listed above were present in exceptionally high amounts and Little James Creek was comprised almost entirely of waste liquors from the Burlington Mine site. As to effects upon James Creek receiving these liquors, changes appeared minimum except for zinc and possibly total dissolved solids. However, sampling of James Creek was not timed in accordance with the intermittent discharges down Little James Creek and in other respects was also inadequate. Damaging effect are believed far more serious than indicated by the available data and additional water quality studies should be conducted to verify the necessity for further waste control and/or treatment facilities at the Burlington Mine.

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